Physics II: 1702
Gravity, Electricity, & Magnetism

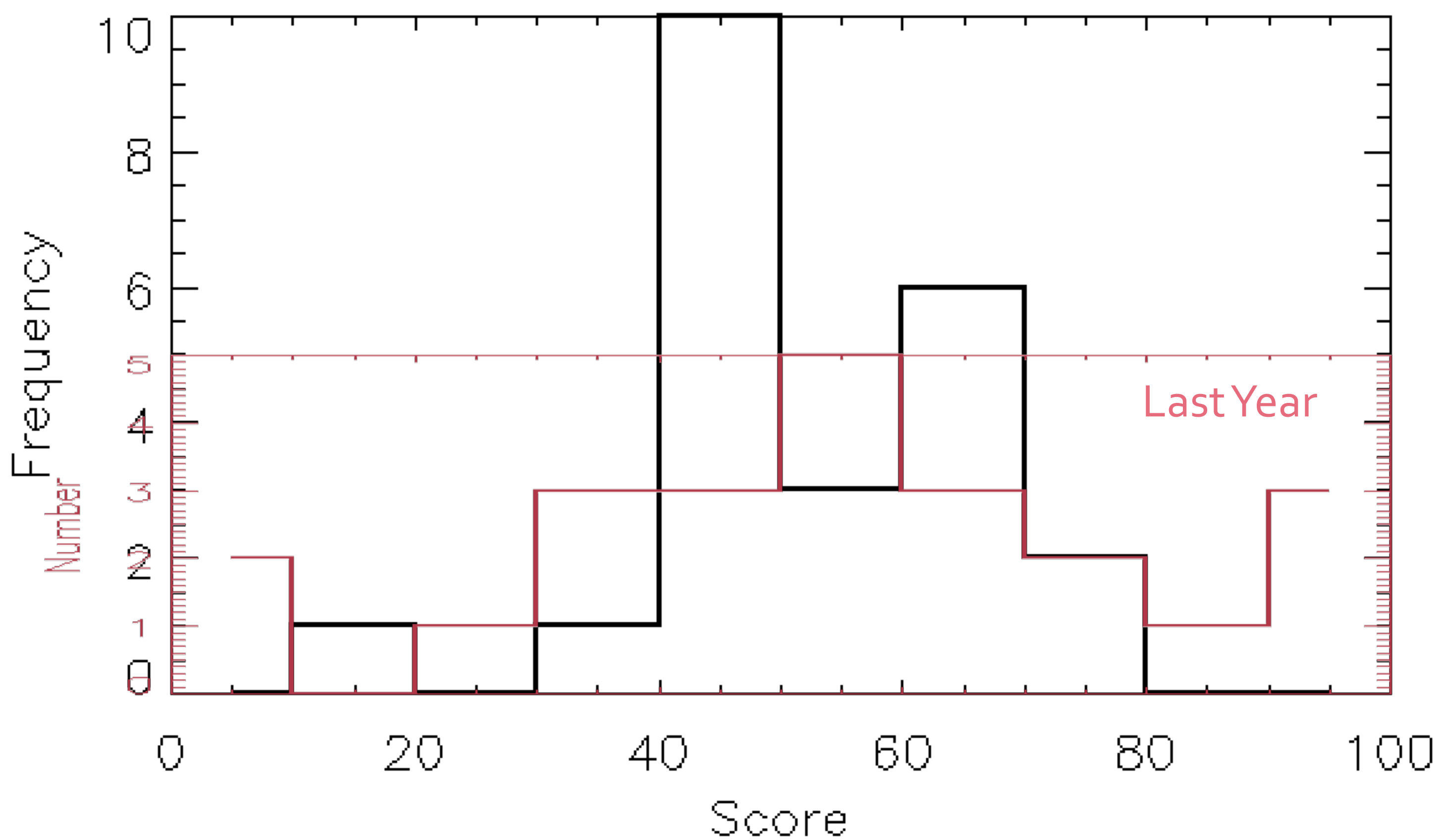
Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Announcements

- Back to regular schedule with lab and homework
  - Lab E4 (Capacitors) on Monday
  - HW5 on Ch. 25 due Wednesday on Wiley Plus

Midterm Results

- Mean = 52, Min = 17, Max = 78



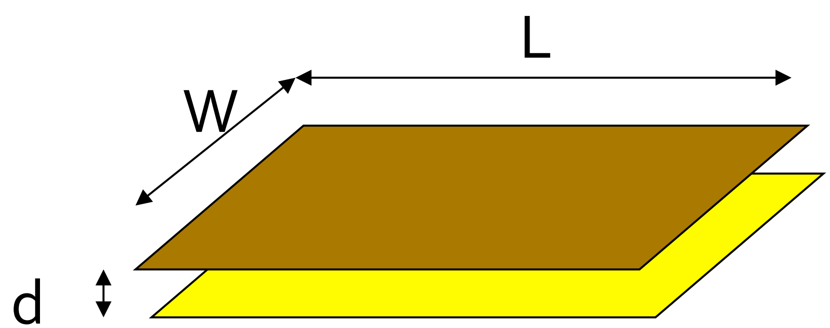
Switching Gears

- Today we will start moving from talking about fields and potentials to thinking about electric circuits
- The first step is capacitance
- $C = Q/V$
  - Capacitance is the capacity to store charge
  - It is a geometric and material property of a system

Capacitor

Capacitor Any two pieces of metal (conductor) brought near each other.

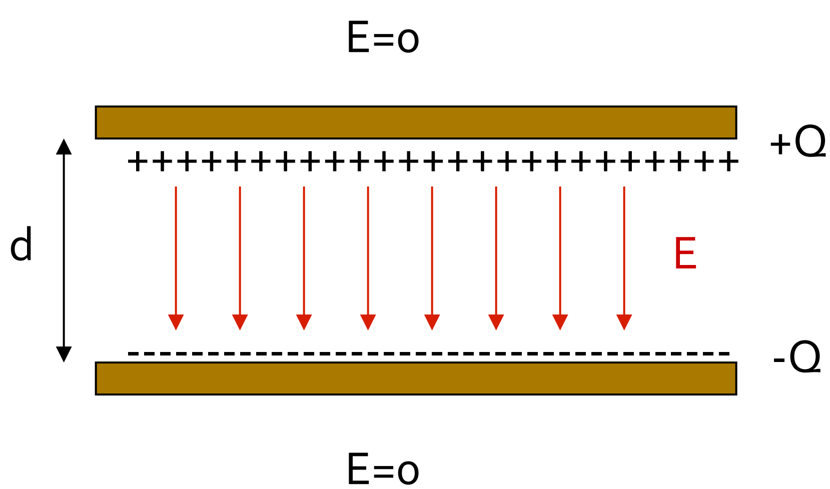
Parallel plate capacitor



Area A = L x W

Parallel Plate Capacitor

"Charged Capacitor" has no <u>net</u> charge, but each portion of a capacitor has charge.

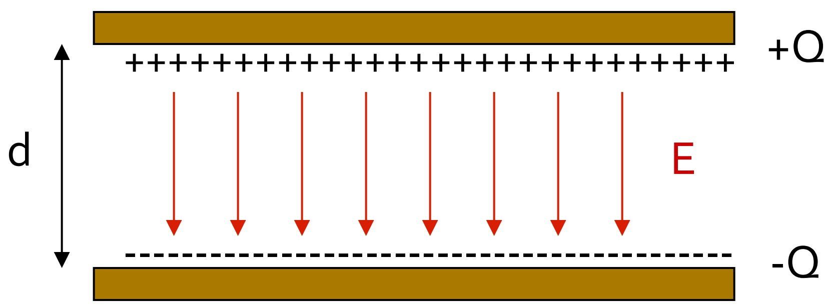


Charges are on the side surfaces of the conductors due to attraction.

Electric Field (treating plates as infinite) and having area A.

$$|\vec{E}| = \frac{\sigma}{\varepsilon_0} = \frac{1}{\varepsilon_0}\left(\frac{Q}{A}\right)$$

Parallel Plate Capacitor



$$V = \Delta V = \int \vec{E} \cdot d\vec{r} = |\vec{E}|\, d$$

$$V = \frac{Q}{(\varepsilon_0 A / d)}$$

Define Capacitance

$$\boxed{C \equiv \frac{Q}{V}}$$

For parallel plate capacitor

$$C \equiv \frac{\varepsilon_0 A}{d}$$

Capacitance Formula Motivated

- Increasing area increases the amount of charge you can store
- Decreasing distance decreases the total voltage drop between two surfaces
- Thus both increase the amount of charge you can store for a given voltage difference

Concept Check

If the charge on a parallel-plate capacitor is doubled:

1) the capacitance is halved
2) the capacitance is doubled
3) the electric field is halved
4) the electric field is doubled
5) the surface charge density is not changed on either plate

Concept Check

Pulling the plates of an isolated charged capacitor apart:

1) increases the capacitance
2) increases the potential difference
3) does not affect the potential difference
4) decreases the potential difference
5) does not affect the capacitance

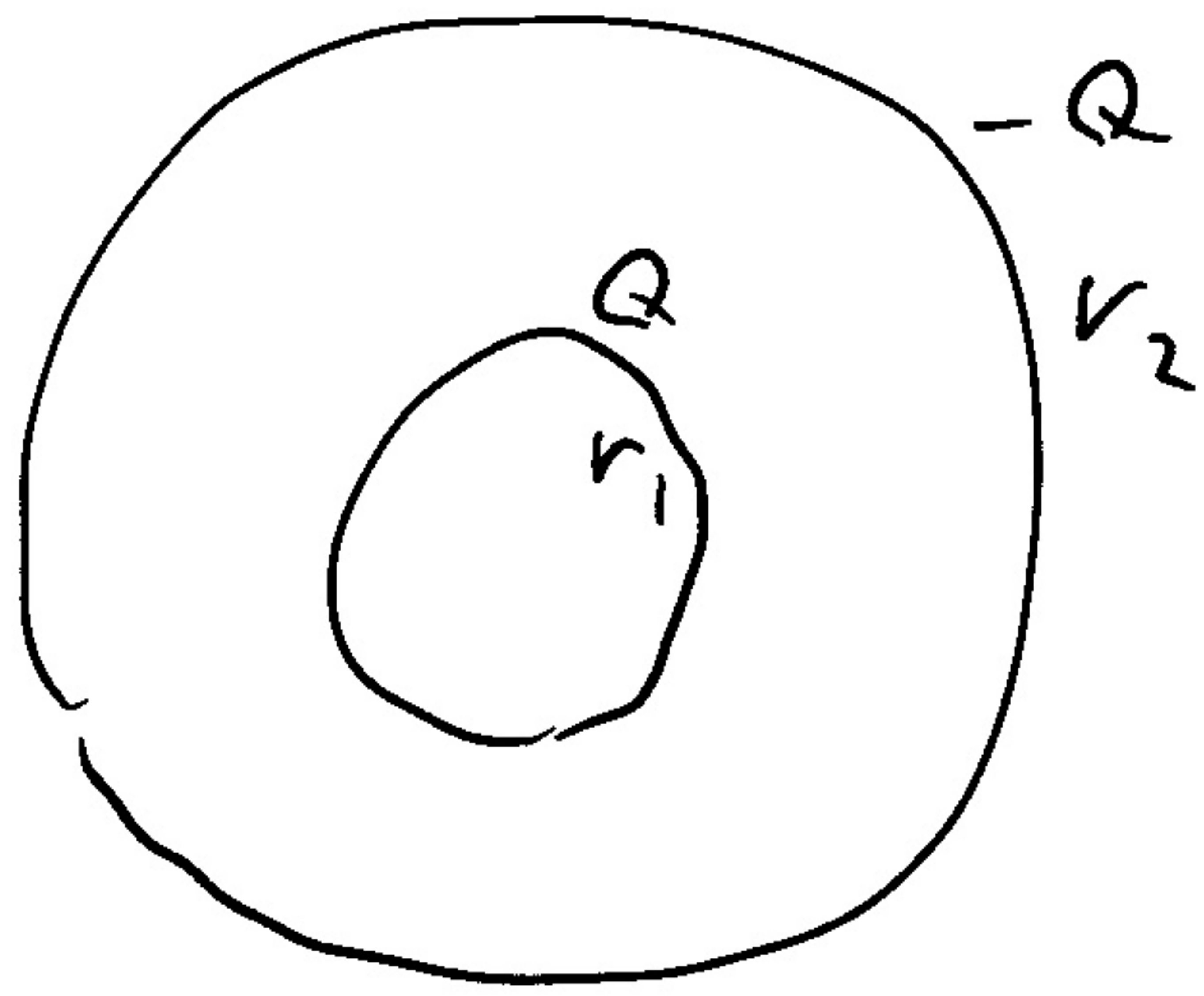
Capacitors in Other Geometries

Formula depends on shape

But, capacitance still depends only on geometry

Spherical Capacitor

Two shells



$r < r_1$: $E = 0$
$r > r_2$: $E = 0$

$r_1 < r < r_2$: Use Gauss's Law or shell theorem

$$\oint \vec{E} \cdot d\vec{A} = E \cdot A = E \cdot 4\pi r^2 = Q/\varepsilon_0$$

$$\Rightarrow \vec{E} = \frac{Q \hat{r}}{4\pi\varepsilon_0 r^2}$$

$$\Delta V = -\int_{r_1}^{r_2} \vec{E} \cdot d\vec{l}$$ put $d\vec{l} = \hat{r}\, dr$

$$= -\int_{r_1}^{r_2} Q/4\pi\varepsilon_0 r^2 \, dr$$

$$= Q/4\pi\varepsilon_0 r \Big|_{r_1}^{r_2}$$

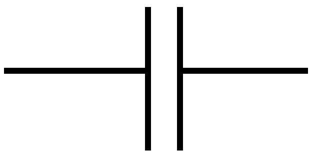
$$= Q/4\pi\varepsilon_0 r_2 - Q/4\pi\varepsilon_0 r_1$$

$$C = Q/|\Delta V| = Q/(Q/4\pi\varepsilon_0 r_1 - Q/4\pi\varepsilon_0 r_2)$$

$$= \boxed{4\pi\varepsilon_0/(1/r_1 - 1/r_2)}$$

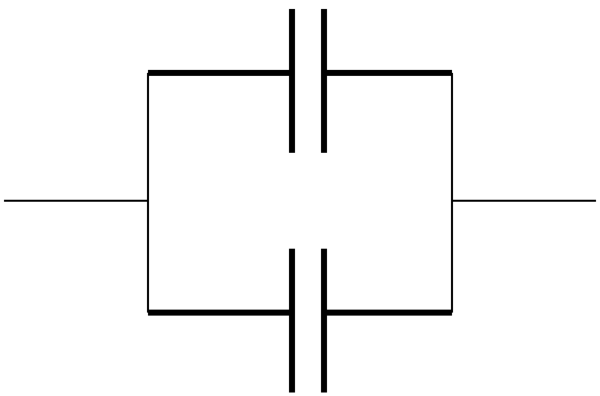
Flux Capacitor

Capacitors Abstracted



Circuit symbol for a capacitor

More than one capacitor?

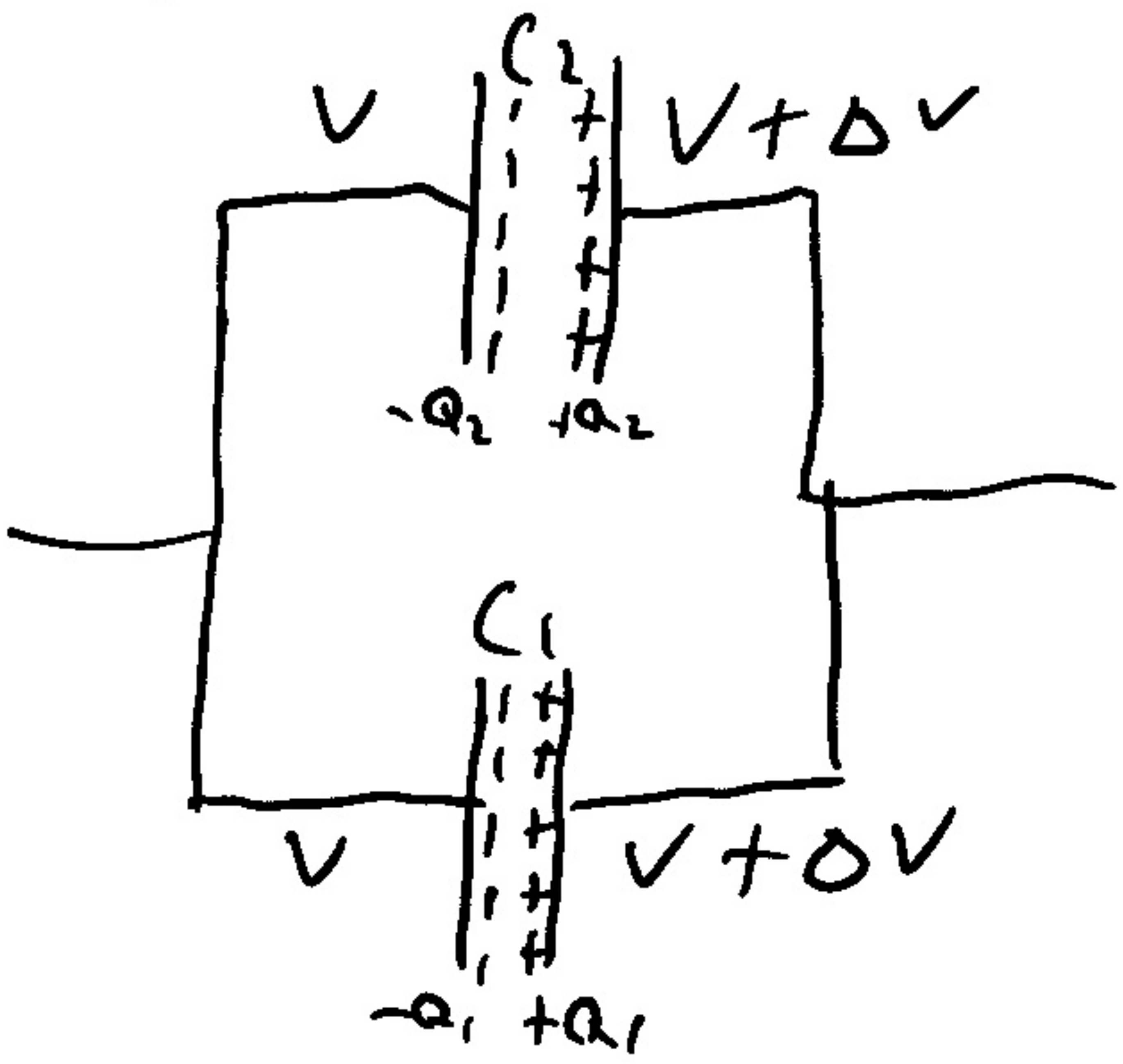


Two capacitors in parallel

$$C_{tot} = C_1 + C_2$$

Think about them like one giant capacitor with the area of 1 and 2 together.

Capacitors in Parallel



$$Q_2 = C_2 (V + \Delta V - V)$$
$$= C_2 \Delta V$$

$$Q_1 = C_1 \Delta V$$

$$Q_{total} = Q_1 + Q_2 = C_1 \Delta V + C_2 \Delta V$$
$$= (C_1 + C_2) \Delta V$$

$$C_{tot} = Q_{total} / \Delta V = C_1 + C_2$$

Concept Check

- A 2-mF and a 1-mF capacitor are connected in parallel and a potential difference is applied across the combination. The 2-mF capacitor has:

1. twice the charge of the 1-mF capacitor
2. half the charge of the 1-mF capacitor
3. twice the potential difference of the 1-mF capacitor
4. half the potential difference of the 1-mF capacitor
5. none of the above